

# PHYTOSEIID PREDATORS OF MITE PESTS IN UTAH APPLE ORCHARDS<sup>1</sup>

Clive D. Jorgensen<sup>2</sup> and Vichitra Mongkolprasith<sup>2,3</sup>

**ABSTRACT.**—Recent efforts to integrate phytoseiid predators in pest (mite) management programs for apples have been somewhat successful and economical in several fruit growing areas of North America. Convenient descriptions and reviews of the literature for species which have been collected from Utah are provided to stimulate further local work. Seven species of *Amblyseius* and five *Typhlodromus* are described (none new), with notes provided concerning their respective geographic distributions and biologies.

Chemical control of phytophagous mites in apple orchards has resulted in pesticide residues toxic to man, death of nontarget species in the agro-ecosystem, inflated expenses, polluted environments, and the development of resistance to numerous pesticides by the pests themselves. To avoid these problems, some pest management programs now include biological agents (predators, parasites, pathogens). Among these agents, phytoseiid predators have received attention because of their numbers, common occurrence with the pests, and important role demonstrated in economically suppressing some pest mite species while avoiding pollution and toxic residues.

Before integrating phytoseiid predators into pest control programs, taxonomic studies should be made to determine the species present and their potentials for pest control. Although phytoseiid mites were studied from an economic standpoint by Parrott et al. (1906), reliable taxonomic identifications were not possible until 1948 when Garman used chaetotaxy of the dorsal and ventrianal shields in his generic revision. Nesbitt (1951) later revised the subfamily using Garman's system of chaetotaxy and suggested several species as important predators of tetranychid mites. Chant (1959) started a series of papers dealing with phytoseiid biology that has led to many useful faunistic and life history studies, i.e., Muma (1961), Pritchard and Baker (1962), Schuster and Pritchard (1963), Chant (1965), Chant and Hansell (1971), Chant et

al. (1974), Oatman (1976), etc. A recent review of the literature (Croft and Brown 1975) was helpful in understanding potential success of phytoseiid predators in pest management of deciduous fruit pests. Additional information has since been prepared by Croft (1975a, 1975b) in summaries of the US/IBP pome and stone fruit pest management research and strategies.

Although phytophagous species have been listed by Jorgensen (1967) for Utah apple orchards, few studies of potential predators have been completed. Except for important life history studies of *Typhlodromus mcgregori* (Croft and Jorgensen, 1969) and *Typhlodromus occidentalis* (Lee and Davis, 1968), little is known of Utah species, and faunal studies have not even been reported.

Descriptions of Utah phytoseiid species on apples are presented below, along with a key for identifying adult females. Classification of the species and genera follows Chant (1965), Chant and Hansell (1971), and Chant et al. (1974). The terminology and chaetotaxy follow Schuster and Pritchard (1963). Seasonal variations and distributions within the trees are not present because they are found for several species in Leetham and Jorgensen (1969), Nelson and Jorgensen (1969), and Duke et al. (1970). The primary objectives of our study are (1) to provide a basis for identifying the predaceous mites that are potentially helpful in pest management of Utah apple orchards and (2) to summarize what is presently known of their respective biologies.

<sup>1</sup>This research was supported, in part, by Grant 12-14-100-3029-(33) from the USDA, Division of Entomology, to Brigham Young University.

<sup>2</sup>Department of Zoology, Brigham Young University, Provo, Utah 84602.

<sup>3</sup>Present address: 7 Group 9, Bangwa, Parichareon, Bangkok, Thailand.

## METHODS

Specimens were collected from derelict and commercial apple orchards throughout the state. The collections were made from all geographic regions and included sampling from leaves, bark from the trunk and major scaffold limbs, and orchard cover and litter from beneath the trees. A mite-brushing machine was sometimes used to collect mites from leaves and twigs. Modified Tullgren funnels were used extensively to remove mites from cover and litter as well as from twigs and leaves, particularly during the winter months. Collections were started in 1966 and continued through 1973, although most collections were made from 1966 to 1971.

Specimens were mounted in Hoyers me-

dium, identified, and drawings made of them with the assistance of a drawing tube. Measurements were taken from intact specimens and routinely checked for accuracy by remeasuring. Although we did not think it was necessary to report complete descriptions and measurements, they are available in Mongkolprasith (1976). Complete descriptions are also referenced with each species discussion.

Nomenclature used for chaetotaxy throughout this paper is included in Figures 1 and 2. Although the lateral setae (laterals) are labeled prolateral and postlateral (Fig. 1), they are numbered sequentially  $L_{1-9}$  in the descriptions; thus (Fig. 1) prolaterals =  $L_{1-6}$ , postlaterals =  $L_{7-9}$ , dorsocentrals =  $D_{2-5}$ , verticals =  $D_1$  and clunals =  $D_6$ .

## RESULTS

Key to the Adult Females<sup>4</sup>

1. Four pairs of prolateral setae on the dorsal plate; never more than a total of nine pairs of lateral setae (Figs. 4-17); genus *Amblyseius* ..... 2
- More than four pairs of prolateral setae on the dorsal plate; 8-12 pairs of lateral setae (Figs. 1, 18-27); genus *Typhlodromus* ..... 8
- 2(1). All setae on the dorsal plate short or minute, none greatly (at least twice as long) longer than the others (Figs. 4, 5) ..... *A. salish*
- At least one pair of setae on the dorsal plate ( $L_1$ ,  $L_4$ ,  $L_9$ , or  $M_2$ ) twice as long as other setae ..... 3
- 3(2). Prolateral setae longer than distances between their bases,  $L_5$  extends beyond the bases of  $L_6$  (Figs. 6, 7) ..... *A. fallacis*
- Prolateral setae shorter than the distances between their bases,  $L_5$  not long enough to reach the base of  $L_6$  ..... 4
- 4(3). Only  $L_9$  at least twice as long as other setae on the dorsal plate (Figs. 8, 9) ..... *A. cucumeris*
- More than one pair of setae (usually  $L_1$ ,  $L_4$ ,  $L_9$ , or  $M_2$ ) on the dorsal plate at least twice as long as others ..... 5
- 5(4).  $D_5$  present on the dorsal plate (Figs. 10, 11) *A. floridanus*..... 6
- $D_5$  absent from the dorsal plate ..... 6
- 6(5).  $L_9$  longer than  $M_2$ , preanal pores behind and almost in line longitudinally with the third preanal setae (Figs. 12, 13) ..... *A. oregonensis*
- $L_9$  slightly shorter than  $M_2$ , preanal pores nearly in line with or slightly in front of the third preanal setae ..... 7

<sup>4</sup>Complete descriptions of each species are cited on the first line under each species heading in this section. For measurements and descriptions of Utah specimens, refer to Mongkolprasith (1976).

- 7(6). Length of  $L_2$  about two-thirds of  $L_1$   $M_2$  and  $L_9$  slightly serrate; macroseta on basitarsus IV longest, shortest on tibia (Figs. 3, 14, 15) ..... *A. rosellus*
- Length of  $L_2$  about five-sixths of  $L_1$   $M_2$  and  $L_9$  smooth. Macroseta on basitarsus IV longest, approximately equal on tibia and genu (Figs. 3, 16, 17) ..... *A. ovatus*
- 8(7). Eight pairs of lateral setae on the dorsal plate ..... 9
- More than eight pairs of lateral setae on the dorsal plate ..... 10
- 9(8). Two pairs of preanal setae on the ventrianal plate (Figs. 18, 19) ..... *T. smithii*
- Four pairs of preanal setae on the ventrianal plate (Figs. 20, 21). ..... *T. columbiensis*
- 10(8). Ten pairs of lateral setae on the dorsal plate (Figs. 22, 23) ..... *T. caudiglans*
- Nine pairs of lateral setae on the dorsal plate ..... 11
- 11(10).  $L_9$  at least twice as long as  $L_8$ , prolateral setae equal to or slightly longer than the distances between their bases and succeeding setae (Figs. 24, 25). ..... *T. mcgregori*
- $L_9$  approximately equal in length to  $L_8$ , lateral setae much longer than the distances between their bases and succeeding setae (Figs. 26, 27) ..... *T. occidentalis*

*Amblyseius salish* Chant & Hansell

Fig. 4, 5

Chant and Hansell, 1971:717, Figs. 97–100, 218

Dorsal plate nearly oval, about twice as long as wide, smooth. Dorsal setae smooth, minute, shorter than distances between their bases and bases of nearest succeeding neighbors. Lateral setae longer than dorsals and increase generally in length posteriorly, but always shorter than distance to the base of the nearest succeeding setae. Two pairs of pores and  $M_2$  closer to  $L_7$  than  $L_8$ . Sublaterals  $S_1$  and  $S_2$  present. Peritremes extend to the base of vertical setae.

Utah specimens agree with data provided by Chant and Hansell (1971) for specimens collected from Canada and Alaska. *Amblyseius salish* has been reported only from Ontario and northwest British Columbia (Chant and Hansell 1971). Utah specimens were collected from bark and leaves of apple trees, and cover and litter from apple orchards in Utah County.

*Amblyseius fallacis* (Garman)

Fig. 6, 7

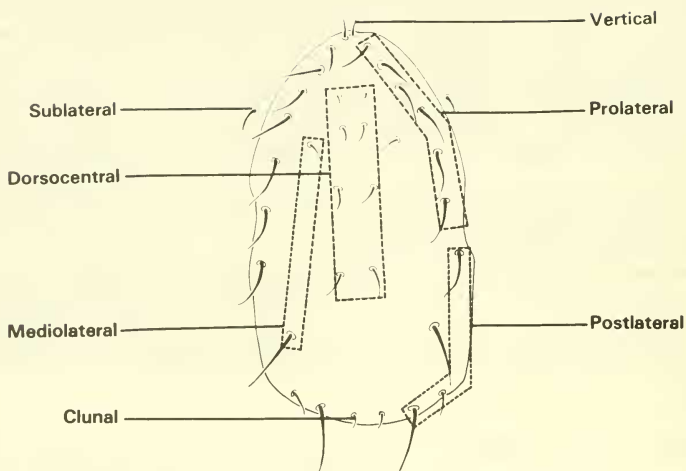
Chant and Hansell, 1971:707, Figs. 8–12, 227

Dorsal plate reticulate and nearly twice as long as wide. Dorsal setae, except  $D_6$ , long and slender, but usually not longer than distances between their bases and the bases of

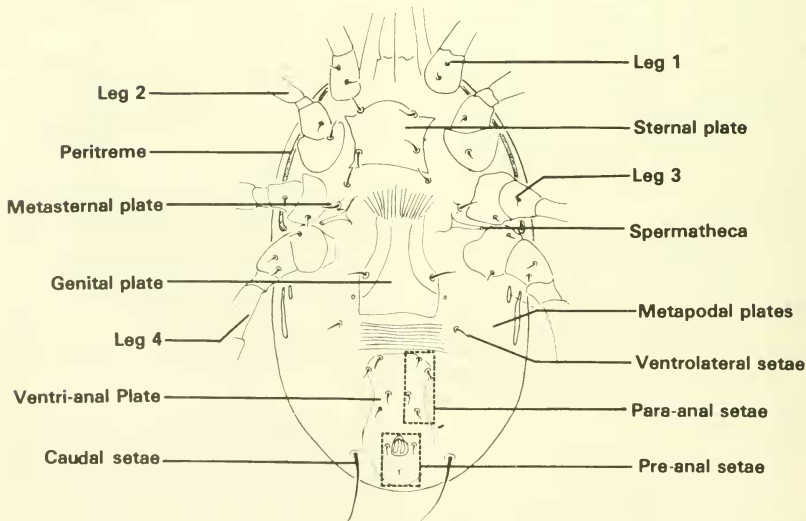
nearest succeeding neighbors. Lateral setae except  $L_4$ , longer than distances between their bases. Sublaterals  $S_1$  and  $S_2$  present. Postscutum with four pairs of pores. Peritremes large and long, extending midway between  $L_1$  and verticals in females and well beyond  $L_1$  in males.

*Amblyseius fallacis* has been separated by previous authors from closely related species as follows: (1) lengths of setae on the dorsal hexagonal area were used to distinguish it from *A. masseei* (Chant 1965, 1957, 1959, and Womersley 1954); (2) relative lengths of  $D_2$  and  $D_3$ , distances between their bases (Chant and Hansell 1971); and (3) number and shape of postscutum and preanal pores were used (Garman 1948 and Schuster and Pritchard 1963) to distinguish it from *A. inornatus*. Utah specimens have  $D_2$  and  $D_3$  longer or equal to the crescentic preanal pores; thus they were determined to be *A. fallacis*.

This species has been reported from throughout North America, parts of Australia (Womersley 1954), and Algeria (Ehara 1966). In Canada, it has been reported from British Columbia (Chant 1957, Anderson et al. 1958a) and eastern Canada (Nesbitt 1951, Chant and Hansell 1971). Specimens have been reported in the United States from Connecticut (Garman 1948), New York (Nesbitt 1951), Virginia (Nesbitt 1951), Washington



1



2

Figs. 1-2. Labeled dorsal (1) and ventral (2) views of *Typhlodromus mcgregori*.

(Nesbitt 1951, Malcolm 1955, Burrell and McCormick 1964), West Virginia (Clancy and McAlister 1958), Wisconsin (Oatman 1965), Ohio (Ballard 1954, Ristich 1956), Maryland (Smith et al. 1963), Illinois (English and Snetsinger 1957), Texas (Dean 1957), California (Schuster and Pritchard 1963) and Utah (Leetham and Jorgensen 1969). Cunliffe and Baker (1953) reported specimens from across the entire northern part of the United States. We collected them from apple leaves and spurs, and apple tree cover from Utah, Wasatch, and Duchesne counties in Utah.

Considerable work has been done on the life history, host species and overwintering of *A. fallacis* (Ballard 1954, Smith and Newsom

1970, Tsung 1972). They have been reported to feed on *Tetranychus telarius*, *Tetranychus canadensis*, *Schoenei mcgregori*, and *Panonychus ulmi* (Nesbitt 1951); *Tetranychus urticae*, *Tetranychus mcdanieli*, *P. ulmi*, and *Bryobia* sp. (Herbert 1959, Burrell and McCormick 1964); and *Tetranychus yusti*, *Tetranychus desertorum*, and *T. urticae* (Smith and Newsom 1970). They have been reported from apple (Garman 1948), peach (Putman and Herne 1964), apple, raspberry, strawberry, bean, corn, dogbane, and clover (Nesbitt 1951); sugar beets, alfalfa, and morning glory (Burrell and McCormick 1964); and asparagus (Tsung 1972). Specimens have been reported overwintering on apple spurs (Leetham and Jorgensen 1969, Tusing 1972) and orchard litter and cover (Putman 1959).

Although Chant (1961) considered *A. fallacis* an unlikely control agent of *T. telarius* in greenhouses, Smith and Newsom (1970) recognized their potential as being rather high for several tetranychid species. They have recently been found to be rather effective in controlling tetranychid species in Michigan and other U.S. apple growing areas east of the Mississippi where they have developed resistance to organic phosphate insecticides (Croft 1975a, 1975c).

*Amblyseius cucumeris* (Oudemans)

Figs. 8, 9

Chant and Hansell, 1971:721, Figs. 129-132, 210

Dorsal plate reticulate, oval, slightly imbricated. Dorsal setae generally smooth and short, all being shorter than distances between their bases and bases of nearest succeeding neighbors, except  $L_8$  longer than intersectional distance between  $L_8$  and  $L_9$ . Prolateral setae shortened, approximately equal in length, sublaterals  $S_1$  and  $S_2$  present. Peritremes extend nearly to base of vertical setae and slightly shorter in males than in females.

Although the Utah specimens fail to satisfy the distinguishing characters described by Chant (1957, 1959) and DeLeon (1959), they agree with Wormersley (1954), Schuster and Gonzales (1963), Schuster and Pritchard (1963), and Chant and Hansell (1971).

This species seems to be found throughout the world, being reported from British Co-

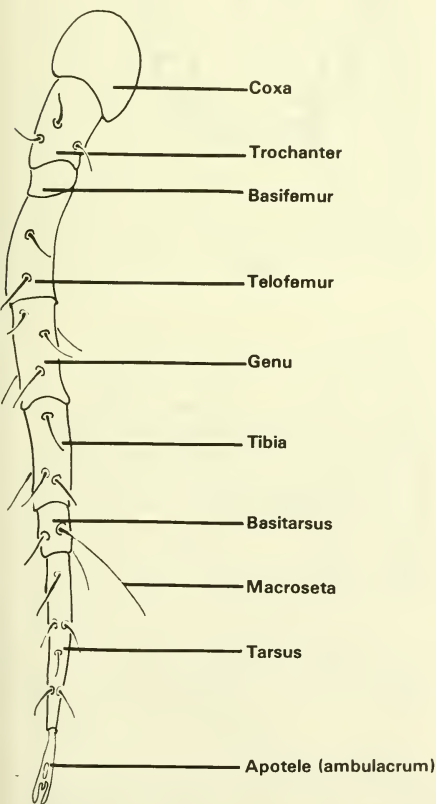
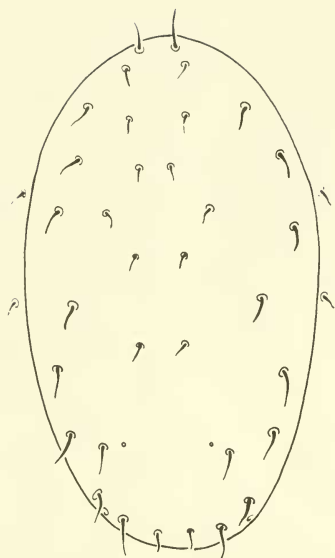
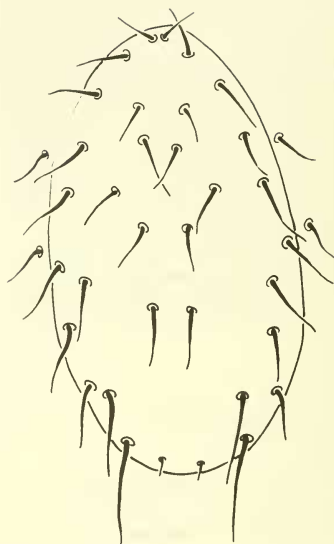


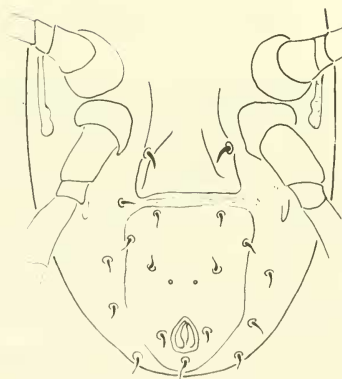
Fig. 3. Labeled leg IV of *Typhlodromus columbiensis*.



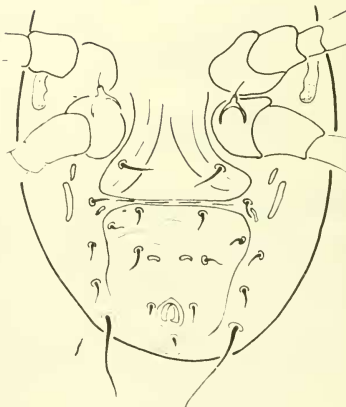
4



6



5



7

Figs. 4-7. Dorsal (4) and ventral (5) views of *Amblyscius salish*, and dorsal (6) and ventral (7) views of *Amblyscius fallacis*.

lumbia, Canada (Chant 1957, Anderson et al. 1958); eastern Canada (Nesbit 1951); England (Collyer 1956); Switzerland, Germany, Netherlands, New Zealand, Mexico, Egypt, Australia (Chant 1959); Algeria (Ehara 1966); and in the United States, Virginia (Collyer 1956), California (Schuster and Pritchard 1963), and Utah (Leetham and Jorgensen 1969). They were collected from apple leaves and bark and apple orchard litter and cover in Utah and Salt Lake counties in Utah.

Life history studies have not been extensive, although considerable work has been reported (Oudemans 1930, MacGill 1939, El-Badry and Zaher 1961). They have been reported feeding on *Steneotarsonemus paplidus* (Huffaker and Kennett 1956), *Panonychus ulmi* and *Bryobia* sp. (Burrell and McCormick 1964), and *Tetranychus cinnabarinus*, *Eutetranychus banksi*, *Oligonychus terminalis*, and *Brevipalpus* sp. (El-Badry and Zaher 1961). Host plants from which they have been collected are beans, dogbane (Nesbitt 1951); cotton (MacGill 1939), tomatoes (Evans 1952); myrobalam, bramble, strawberry (Collyer 1956); peach (Putman 1959); eggplant, ornamentals, several fruit trees (El-Badry and Zaher 1961); and violets, sugar beets, and white sage (Burrell and McCormick 1964).

#### *Amblyseius floridanus* (Muma)

Figs. 10, 11

Schuster and Pritchard, 1963:234, Fig. 24

Dorsal plate oval, smooth, broadest behind legs IV. Dorsal setae smooth, minute except  $D_1$  longer than others. Prolateral setae (except  $L_1$ ) shorter than distances from their bases and bases of nearest succeeding neighbors. Dorsal setae  $M_2$ ,  $L_1$ ,  $L_4$ , and  $L_9$  much longer than other setae. Sublaterals  $S_2$  slightly shorter than  $S_1$ . Peritremes extend slightly beyond  $L_9$ .

Muma (1955) stated that *A. floridanus* has no preanal pores, but the Utah specimen agrees with descriptions by Garman (1958), Schuster, and Pritchard (1963), and Muma (1964).

This species has been reported from Hong Kong and Algeria (Ehara 1966), and, in the United States, from Florida (Garman 1948, Muma 1955), California, Oregon, Washing-

ton, and New Mexico (Schuster and Smith 1960, Schuster and Pritchard 1963), and Utah (Leetham and Jorgensen 1969). In Utah, *A. floridanus* was collected from Utah and Cache counties on apple leaves and in the litter and cover of apple orchards. Biological research has apparently not yet been done.

#### *Amblyseius oregonensis* (Garman)

Fig. 12, 13

Chant 1959:91, Figs. 196-197

Dorsal plate smooth, oval. Dorsal setae smooth, minute, with  $D_5$  missing, always shorter than distances from their bases to bases of nearest succeeding neighbors. Lateral setae longer than dorsals,  $L_4$ ,  $L_9$ , and  $M_2$  much longer than other laterals with  $L_9$  at least twice as long as others. Two pairs of pores. Sublaterals  $S_1$  and  $S_2$  present. Peritremes extend to bases of vertical setae.

Although some Utah specimens resemble descriptions of *Amblyseius rosellus* reported by Chant and Baker (1965), they agree specifically with descriptions for *A. oregonensis* in Garman (1958) and Chant (1959).

*Amblyseius oregonensis* has been reported from Washington and Connecticut (Garman 1948). In Utah, they have been collected from apple leaves and bark from Utah and Cache counties, and cover, litter, and soil in Utah County. Biological research with this species has apparently not yet been done.

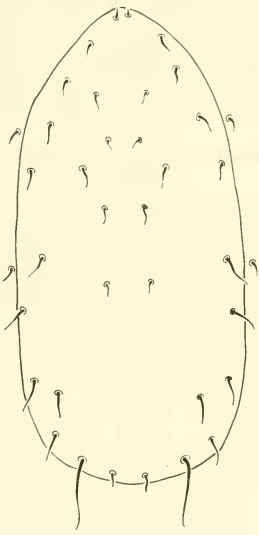
#### *Amblyseius rosellus* (Chant)

Figs. 14, 15

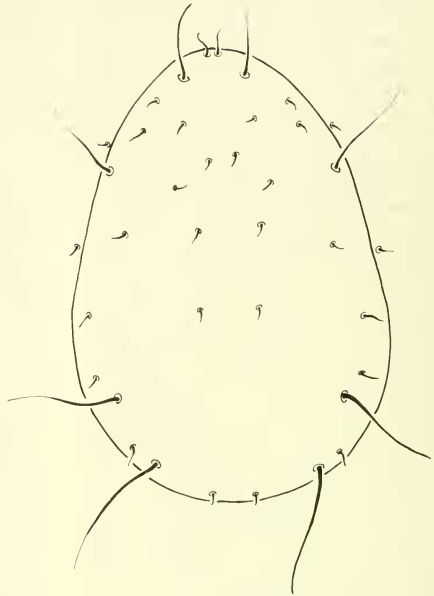
Chant and Baker, 1965:18, Figs. 94-98

Dorsal plate oval, usually smooth, sometimes slightly reticulated near margins. Dorsal setae smooth, minute, always shorter than distances from their bases to bases of nearest succeeding neighbors. Lateral setae unequal in length;  $M_2$ ,  $L_4$ , and  $L_9$  much longer than other setae. Sublaterals  $S_1$  and  $S_2$  present. Dorsal plate with two pairs of pores. Peritremes extend to bases of vertical setae.

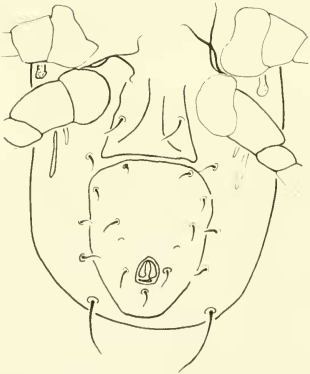
This species has been reported from the West Indies (Chant 1959) and Mexico and Central America (Chant and Baker 1965). Specimens have been collected only from apple orchard cover in Utah County, Utah. Biological research with this species has apparently not yet been done.



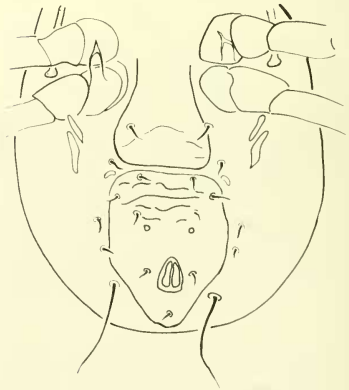
8



10

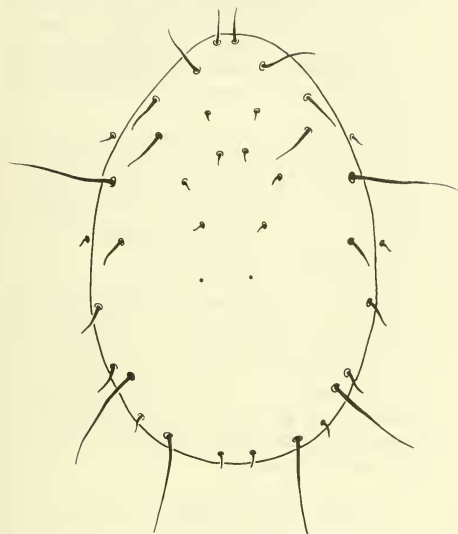


9

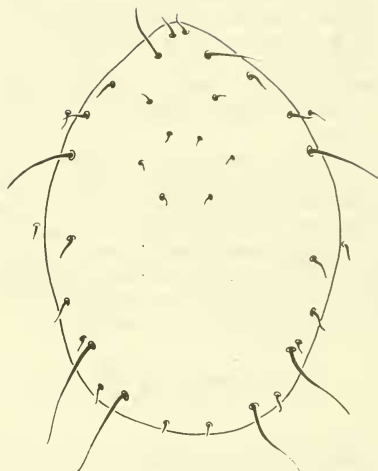


11

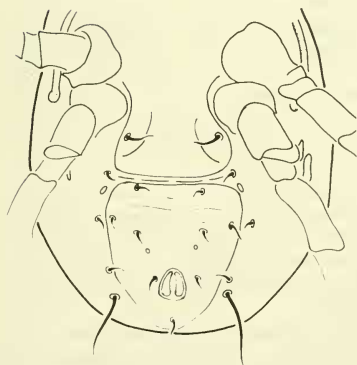
Figs. 8-11. Dorsal (8) and ventral (9) views of *Amblyseius cucumeris*, and dorsal (10) and ventral (11) views of *Amblyseius floridanus*.



12



14



13



15

Figs. 12-15. Dorsal (12) and ventral (13) views of *Amblyseius oregonensis*, and dorsal (14) and ventral (15) views of *Amblyseius rosellus*.

*Amblyseius ovatus* (Garman)

Figs. 16, 17

Schuster and Pritchard, 1963:246, Fig. 33

Dorsal plate smooth, about two-thirds as wide as long. Dorsal setae smooth, minute, always shorter than distances from their bases to bases of nearest succeeding neighbors. Lateral setae unequal in length;  $M_2$ ,  $L_4$ , and  $L_9$  much longer than other setae. Sublaterals  $S_1$  and  $S_2$  present. Dorsal shield with two pairs of pores. Peritremes extend to bases of vertical setae.

*Amblyseius ovatus* has been reported from Equador and Central America (Garman 1948, Chant and Baker 1965), and in the United States from Texas, Florida (Garman 1948, Chant and Baker 1965), Missouri (Poe and Enns 1969), and Utah (Leetham and Jorgensen 1969). Biological research with this species has apparently not yet been done.

*Typhlodromus smithii* (Schuster)

Figs. 18, 19

Schuster, 1975:203, Figs. a-g

Dorsal plate oval, slightly to distinctly reticulate from anterior to posterior. Dorsal setae short, slender, always equal to or shorter than distances from their bases to bases of nearest succeeding neighbors. Prolateral setae on dorsal plate shorter than distances between their bases. Sublateral  $S_1$  equal in length to its associated lateral seta;  $S_2$  slightly longer than its associated lateral seta. Peritremes moderately long, extending to middle of coxa II.

Schuster and Pritchard (1963) revised Schuster's (1957) description and reduced the peritreme length to  $S_1$ . Specimens from Utah agree with the original description, extending the peritremes to coxa II.

This species has been reported from western North America by Schuster (1957) and Schuster and Smith (1960). In Utah, it was collected only from apple tree bark in Utah County. Biological research with this species has apparently not yet been done.

*Typhlodromus columbiensis* (Chant)

Figs. 20, 21

Chant et al., 1974:1271, Figs. 19-21

Dorsal plate reticulate, slightly ridged, es-

pecially at posterior end. Dorsal setae smooth, shorter than distances from their bases to bases of nearest succeeding neighbors, increasing in length posteriorly, except  $D_1$  and  $D_6$ .  $S_1$  slightly posterior to  $L_4$  and  $S_2$  closer to  $L_6$  than to  $L_7$ . Peritremes narrow and extending to vertical setae in females and one-half distance between vertical setae and  $L_1$  in males.

Descriptions of Utah specimens agree with the diagnostic characters provided by Chant et al. (1974), and Muma (1961), and, although  $M_2$  fails to exceed the distance between its base and  $L_7$  as described by Chant (1959), they are clearly *T. columbiensis*.

Until this species was reported from Utah by Leetham and Jorgensen (1969) they were known only from British Columbia and Alaska (Chant 1959, Chant et al. 1974). Specimens from Utah were collected from apple bark and leaves from Utah, Cache, and Davis counties; and from apple orchard cover in Utah County. Biological research has apparently not yet been done.

*Typhlodromus caudiglans* (Schuster)

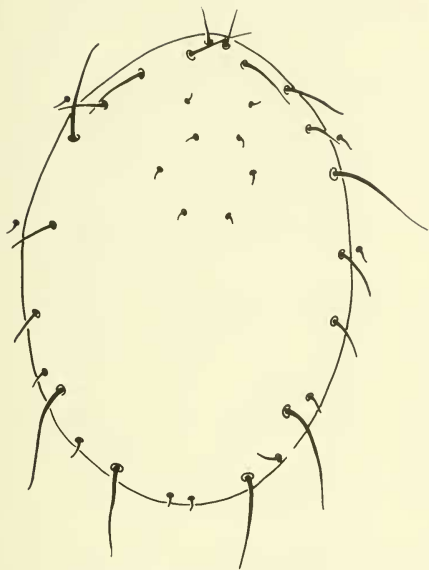
Figs. 22, 23

Chant et al. 1974:1258, Figs. 80-83

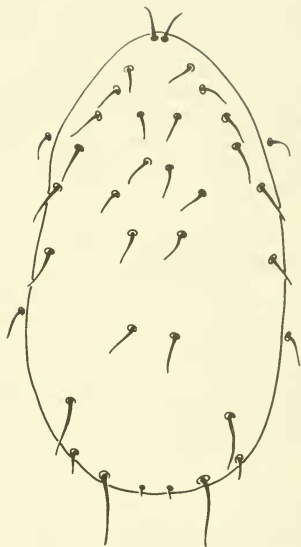
Dorsal plate about one-third longer than wide, lateral margins somewhat concave, surface appears imbricated. Dorsal setae short, slender, all but  $L_9$  shorter than distances between bases of nearest succeeding neighbors. Prolateral setae on dorsal shield shorter than distances between their bases. Sublaterals  $S_1$  and  $S_2$  present and equal in length. Peritremes extend slightly beyond  $L_1$  setae but not to vertical setae.

Although the Utah specimens possess macrosetae on leg IV that Chant (1959) and Schuster (1959) failed to observe, they conform to the redescrptions submitted by Schuster and Pritchard (1963) and Chant et al. (1974).

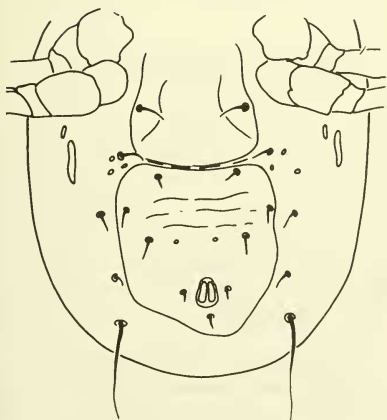
This species has been reported from Egypt (El Badry and Zaher 1961), New Zealand and England (Collyer 1964) and throughout Canada (Chant et al. 1974). In the United States *T. caudiglans* has been reported from California (Chant 1959, Schuster 1959, Schuster and Pritchard 1963, Chant et al. 1974), Wisconsin (Oatman 1960), western North America (Schuster and Smith 1969), and Utah (Lee-



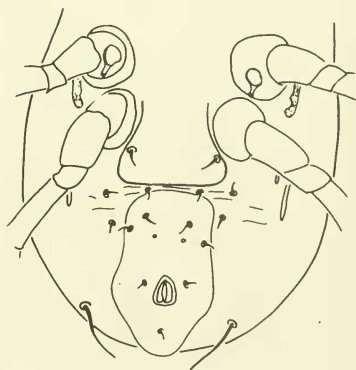
16



18

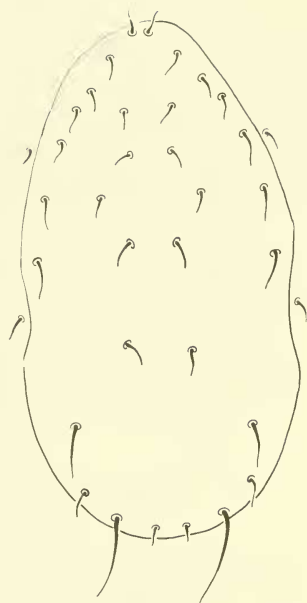


17

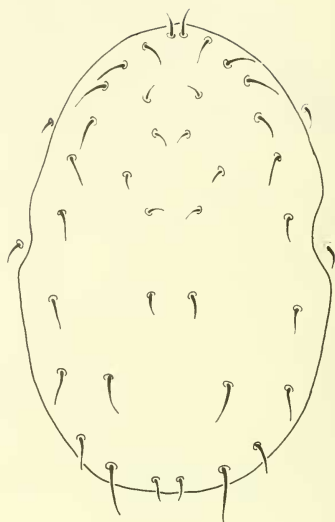


19

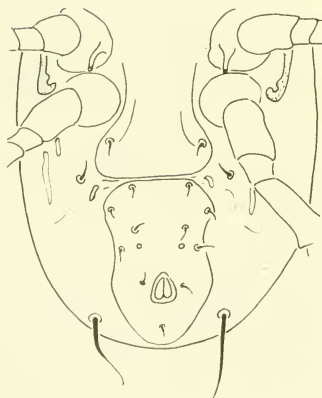
Figs. 16-19. Dorsal (16) and ventral (17) views of *Amblyseius ovatus*, and dorsal (18) and ventral (19) views of *Typhlodromus smithii*.



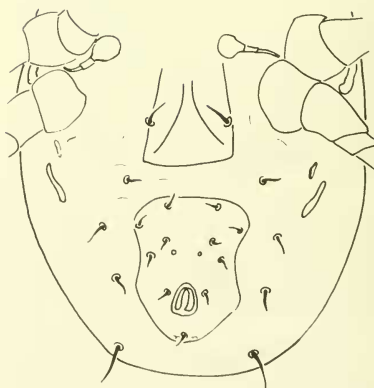
20



22



21



23

Figs. 20-23. Dorsal (20) and ventral (21) views of *Typhlodromus columbiensis*, and dorsal (22) and ventral (23) views of *Typhlodromus caudiglans*.

tham and Jorgensen 1969). In Utah, specimens were collected from apple leaves and spurs in Utah, Cache, and Duchesne counties.

Life history studies have been provided by Schuster (1959) and Putman (1962). Putman (1962) found them able to reproduce on pollen and fungal spores, but not on *Tetranychus telarius* eggs. They have also been reported feeding on *Panonychus ulmi* and *Panonychus citri* (McMurtry and Scriven 1964) active stages, *Bryobia arborea* and *Aculus cornutus* (Putman 1962). Although specimens are found on leaves (Putman and Herne 1964), they seem to move freely from bark and spurs to leaves and back again (Putman 1962, Putman and Herne 1964). The variety of "host" trees also seems to influence movement and relative abundance. Putman (1962) and Putman and Herne (1964) found greater movement on peach than apple, and Downing and Moilliet (1967) found them more numerous on Spartan and McIntosh apple varieties than on Delicious.

Generally, because of feeding habits and habitat selection, *T. caudiglans* cannot be considered a good prospect in integrated pest management programs. Clearly, more research is required to demonstrate positive considerations.

#### *Typhlodromus mcgregori* (Chant)

Figs. 24, 25

Chant et al., 1974:1281, Figs. 54-57

Dorsal plate slightly reticulate, stippled with small punctuations over its entire surface. Dorsal setae short, usually shorter than distances from their bases to bases of nearest succeeding neighbors. Prolateral setae on dorsal plate long, extending to and slightly beyond bases of succeeding setae. Sublateral  $S_2$  absent. Peritremes extend to bases of vertical setae.

The character used by Chant (1959), Chant et al. (1974), and Schuster and Pritchard (1963) to separate *T. mcgregori* from *T. flumenis* was the respective lengths of prolateral setae relative to the distances between their bases. In *T. mcgregori* the setae are equal to or slightly longer than the distances between their bases, and distinctly shorter than the bases in *T. flumenis*. In 1974, Chant

also used the elongated cervix of the spermathecae and the absence of a plate for the third pair of sternal setae as effective separating characters. Muma (1963) stated that *T. mcgregori* could be separated from *T. flumenis* if the length of  $L_8$  was slightly less than twice the distance between  $L_8$  and  $L_9$ , and if  $M_2$  failed to extend beyond the base of  $L_8$ . Utah specimens failed to satisfy Muma's (1963) criteria, but since they agree with the other three authors, they are considered to be *T. mcgregori*.

This species has been reported from Mexico and Canada (Chant 1959), as well as numerous localities in the United States: Alaska, Maryland, Virginia, Ohio, and western United States (Chant et al. 1974), Florida (Muma 1963, Muma and Denmark 1970), California, Arizona, Nevada, New Mexico, and Washington (Schuster and Pritchard 1963), Missouri (Poe and Enns 1969), and Oregon and Utah (Jorgensen 1964, 1967, Leetham and Jorgensen 1969).

Although *T. mcgregori* was reported in North America as early as 1953 (Cunliffe and Baker 1953), it wasn't until Croft and Jorgensen (1969) reported on its life history that any biology was known. This predator has been shown to feed on *Tetranychus pacificus* and *Eotetranychus wallamettei* (Schuster and Pritchard 1963, Schuster 1966), *Panonychus ulmi* (Poe and Enns 1969, Croft and Jorgensen 1969), *Tetranychus urticae* and *Bryobia rubrioculus*, the latter being preferred in Croft and Jorgensen's (1969) work. Croft and Jorgensen (1977) later found *Aculus schlectendali* to be essential to significant predation on *B. rubrioculus*, but reported the former to be its preferred prey. *Typhlodromus mcgregori* also develops larger numbers when feeding on the eriophyids *Aculus coronatus* and *Eriophyes pyri* (Croft and Jorgensen 1977). They inhabit all portions of apple trees as well as cover, litter, and soil beneath them (Leetham and Jorgensen 1969, Dodoo 1968, Poe and Enns 1969). In addition they have been reported from grape (Schuster 1966, Flaherty and Huffaker 1970) and *Malva* sp. (Muma and Denmark 1970). In Utah they have been collected from apple leaves, bark, spurs, and cover and litter beneath the trees in all counties sampled.

Their potential as agents in an integrated

pest management program has been questioned by Duke et al. (1970) and Croft and Jorgensen (1969, 1977) because (1) they are tied too closely to *B. rubrioculus* and *A. schlectendali* in abandoned orchards, (2) their distribution is not efficiently correlated with most pests, (3) their population growth is slow, and (4) their searching behavior restricts contact with most prey species.

*Typhlodromus occidentalis* (Nesbitt)

Figs. 26, 27

Chant et al., 1974:1276, Figs. 34-27

Dorsal plate oval, highly reticulate in female, especially posterior portion. Dorsal setae sometimes slightly plumose, usually longer than distances from their bases to bases of nearest succeeding neighbors.  $D_6$  minute,  $S_2$  absent,  $S_1$  shorter than associated laterals and sometimes slightly plumose. Peritremes short, extending nearly to  $L_5$ , about two-thirds distance between  $L_5$  and  $L_6$ .

Although descriptions of the Utah specimens fail to completely satisfy those provided by Nesbitt (1951), Chant (1959), and Schuster and Pritchard (1963), they are completely agreeable with descriptions by Kennett (1958), Muma (1963), and Chant et al. (1974). Utah specimens are generally larger than others (Hoying and Croft 1977), but they fall within the variation reported by David (1970). They also satisfy the morphological analyses reported by Hoying and Croft (1977) in their comparative studies of *T. occidentalis* and *Typhlodromus longipilus*.

*Typhlodromus occidentalis* has been reported from all regions of temperate North America, although they were most frequently reported from western United States (Chant 1957, 1959, Chant et al. 1974, Anderson et al. 1958, Schuster and Smith 1960, Schuster and Pritchard 1963, and Muma 1963). After careful study Hoying and Croft (1977) reported *T. occidentalis* from only western North America, possibly being replaced by *T. longipilus* in the more humid east. In Utah, they were found wherever derelict orchards were sampled and in most commercial orchards.

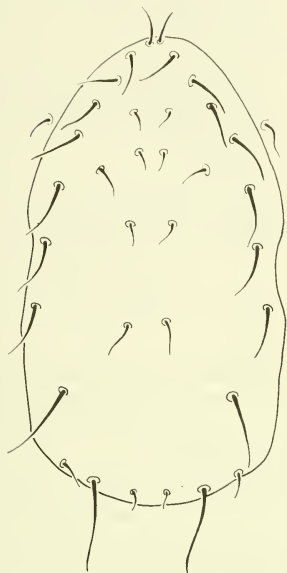
This nearly ubiquitous species was first studied by Nesbitt (1951), but shortly thereafter several life history studies were reported (Lee and Davis 1968, Laing 1969, Croft

and McMurtry 1972). They have been reported to feed on *Tetranychus telarius* (Nesbitt 1951, Kenneth 1958, Leigh 1963, Muma 1963, Schuster and Pritchard 1963), *Tetranychus willamettei* (Schuster and Pritchard 1963, Flaherty and Huffaker 1970), *Tetranychus pacificus* (Schuster and Pritchard 1963, Chant 1961, Croft and McMurtry 1972, Flaherty and Huffaker 1970), *Tetranychus urticae* (Chant 1961, Croft and McMurtry 1972, Lee and Davis 1968), and *Tetranychus mcdanieli* (Hoyt 1969). Apparently there are distinct strains, possibly resulting from varying insecticide schedules (Croft and McMurtry 1972). Comparative studies of these strains have been reported for reproductive isolation (Croft 1970) and pesticide resistance (Croft and Barnes 1972). Their "host" plants are so varied and numerous that itemizing them would not be particularly useful, because they can be expected to occur on almost any plant where their varied prey species occur. In Utah they have been collected from apple leaves, bark, and spurs, as well as cover beneath apple leaves. Collections have been made in Utah, Salt Lake, Uintah, Cache, San Juan, and Emery counties.

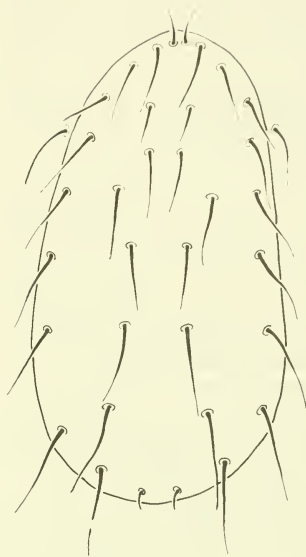
This species has shown some capacity to provide economic control of tetranychid species if managed properly (Lee and Davis 1968, Leetham and Jorgensen 1969, Hoyt 1969a, 1969b, Croft 1975a, 1975b, 1975c), although Anderson and Morgan (1958a) had considered it rather unlikely earlier. At the present time, *T. occidentalis* has more apparent potential than any of the other species in integrated pest management programs in Utah.

#### SUMMARY

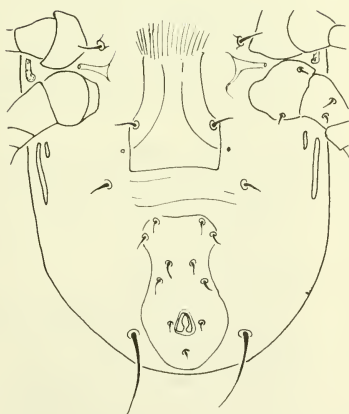
The control of mite pests in Utah apple orchards has been reviewed in a series of topical papers by Davis (1955, 1956, 1959, 1967, 1970) and Jorgensen (1967). We have attempted to consolidate existing information along with much that is new to establish the basis of our present knowledge. Phytoseiid mites were collected from commercial and derelict apple orchards throughout the past and present major fruit-growing areas of Utah. Mites were collected from as many



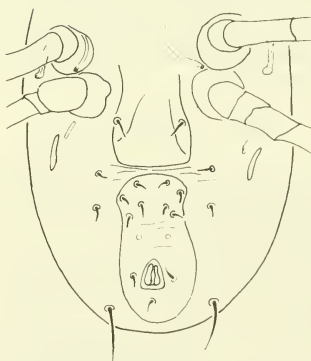
24



26



25



27

Figs. 24-27. Dorsal (24) and ventral (25) views of *Typhlodromus mcgregori*, and dorsal (26) and ventral (27) views of *Typhlodromus occidentalis*.

habitats as possible and during all seasons.

Twelve species were collected and identified; some were rather infrequently recorded, and others were almost ubiquitous throughout the state. Least common were *A. floridanus*, *A. oregonensis*, *A. rosellus*, and *T. smithii*; common were *A. salish*, *A. fallacis*, *A. ovatus*, and *T. caudiglans*; and most common were *A. cucumeris*, *T. columbiensis*, *T. mcgregori*, and *T. occidentalis*. Only *A. fallacis*, *A. cucumeris*, *T. caudiglans*, *T. mcgregori*, and *T. occidentalis* have had sufficient life history research reported to assess their potential value as integrated agents into pest management programs. Additional work is essential for a complete understanding of most species, but may not be advisable as one considers their projected potential.

*Amblyseius fallacis* and *T. occidentalis* each have proven to be valuable in integrated pest management programs. This is partially due to their developed resistance to organic phosphate pesticides, but they also have biological qualities that assist their usefulness. Future research would seem to be best if directed to integrating these two species more completely into possibly pest management programs in Utah rather than working with species with less potential. *Typhlodromus occidentalis* is already partially successful where managed properly, but a great deal more work needs to be done with *A. fallacis* in Utah.

#### LITERATURE CITED

- ANDERSON, N. H., AND C. V. G. MORGAN. 1958a. The role of *Typhlodromus* sp. in British Columbia apple orchards. Proc. 10th Intern. Congr. Entomol., Montreal 4:659-665.
- . 1958b. Life histories and habits of the clover mite, *Bryobia praetiosa* Koch and the brown mite, *B. arborea* M. & A. in British Columbia. (Acarina: Tetranychidae). Can. Entomol. 90:23-42.
- ANDERSON, N. H., C. V. G. MORGAN, AND D. A. CHANT. 1958. Notes on the occurrence of *Typhlodromus* and *Phytoseius* sp. in southern British Columbia. (Acarina: Phytoseiidae). Can. Entomol. 90:275-279.
- BALLARD, R. C. 1954. The biology of the predaceous mite *Typhlodromus fallacis* (Garman) (Phytoseiidae) at 8°F. Ohio J. Sci. 54:175-179.
- BURRELL, R. W., AND W. T. MCCORMICK. 1964. *Typhlodromus* and *Amblyseius* (Acarina: Phytoseiidae) as predators on orchard mites. Ann. Entomol. Soc. Amer. 57:483-487.
- CHANT, D. A. 1956. Some mites of subfamily Phytoseiinae (Acarina: Laelaptidae) from southeastern England with descriptions of new species. Can. Entomol. 88:26-37.
- . 1957. Description of some phytoseiid mites (Acarina: Phytoseiidae). Part I. Nine new species from British Columbia with key to the species of British Columbia. Part II. Redescription of eight species described by Berlese. Can. Entomol. 89:289-308.
- . 1959. Phytoseiid mites (Acarina: Phytoseiidae). Part I. Bionomics of seven species in southeastern England. Part II. A taxonomic review of the family Phytoseiidae, with descriptions of 38 new species. Can. Entomol. 91, suppl. 12, 166 pp.
- . 1961. The effect of prey density on prey consumption and oviposition in adults of *Typhlodromus* (T.) *occidentalis* Nesbitt (Acarina: Phytoseiidae) in the laboratory. Can. J. Zool. 39:311-315.
- . 1965. Generic concepts in the Phytoseiidae (Acarina: Mesostigmata). Can. Entomol. 97:351-374.
- CHANT, D. A., AND E. W. BAKER. 1965. The Phytoseiidae (Acarina) of Central America. Mem. Entomol. Soc. Can. 41:1-56.
- CHANT, D. A. AND R. I. C. HANSELL. 1971. The genus *Amblyseius* (Acarina: Phytoseiidae) in Canada and Alaska. Can. J. Zool. 49:703-758.
- CHANT, D. A., R. I. C. HANSELL, AND E. YOSHIDA. 1974. The genus *Typhlodromus* Scheuten (Acarina: Phytoseiidae) in Canada and Alaska. Can. J. Zool. 52:1265-1291.
- CLANCY, D. H., AND H. T. McALISTER. 1958. Effects of spray practices on apple mites and their predators in West Virginia. Proc. 10th Intern. Congr. Entomol., Montreal 4:597-601.
- COLLYER, E. 1956. Notes on the biology of some predacious mites on fruit trees in southeastern England. Bull. Entomol. Res. 47:205-214.
- . 1964. Phytophagous mites and their predators in New Zealand orchards. N. Z. J. Agr. Res. 7:551-568.
- CROFT, B. A. 1970. Comparative studies on four strains of *Typhlodromus occidentalis* Nesbitt (Acarina: Phytoseiidae) I. Hybridization and reproductive isolation studies. Ann. Entomol. Soc. Amer. 63:1558-1563.
- . 1975a. Integrated control of orchard pests in the U.S.A. C. R. 5th Sump. Sutte Integree Vergers OILB/SROP: 109-124.
- . 1975b. Tree fruit pest management (In: Introduction to insect pest management, ed. W. G. Luckmann and R. H. Metcalf). John Wiley & Sons, New York: 471-507.
- . 1975c. Integrated control of apple mites. Mich. State Univ. Exten. Bull. E-825: 12 pp.
- CROFT, B. A., AND M. M. BARNES. 1972. Comparative studies on four strains of *Typhlodromus occidentalis*. VI. Persistence of insecticide-resistant strains in an apple orchard ecosystem. J. Econ. Entomol. 65:211-216.
- CROFT, B. A., AND A. W. A. BROWN. 1975. Responses of arthropod natural enemies to insecticides. Ann. Rev. Entomol. 20:285-335.

- CROFT, B. A., AND C. D. JORGENSEN. 1969. Life history of *Typhlodromus mcgregori* (Acarina: Phytoseiidae). Ann. Entomol. Soc. Amer. 62:1261-1267.
- . 1977. *Typhlodromus mcgregori* Chant (Acarina: Phytoseiidae) and its control of phytophagous mites in Utah and southern California apple orchards. Great Basin Nat. 37:366-374.
- CROFT, B. A., AND J. A. MCMURTRY. 1972. Comparative studies on four strains of *Typhlodromus occidentalis* Nesbitt (Acarina: Phytoseiidae). IV. Life history studies. Acarologia 13:460-469.
- CUNLIFFE, F., AND E. W. BAKER. 1953. A guide to the predatory phytoseiid mites of the United States. Pinellas Biol. Lab. Publ. No. 1. (no pagination.)
- DAVIS, D. W. 1955. Mites of horticultural interest. Proc. Utah Hort. Soc., p. 52-56.
- . 1956. The spider mite situation in Utah. Proc. Utah Acad. Sci. 33:179-180.
- . 1959. Mite control. Utah Farm and Home Sci. 20:22-23.
- . 1967. McDaniel mites and the resistance problem in Utah. Utah Farm and Home Sci. 28:26-27, 31.
- . 1970. Integrated control of apple pest in Utah. Utah Sci. 31:43-45, 48.
- . 1970. Variations in the anatomy of *Typhlodromus occidentalis*. Ann. Entomol. Soc. Amer. 63:696-699.
- DEAN, H. A. 1957. Predators of *Oligonychus pratensis* (Banks), Tetranychidae. Ann. Entomol. Soc. Amer. 50:164-165.
- DELEON, D. 1959b. Seven new *Typhlodromus* from Mexico with collection notes on three other species (Acarina: Phytoseiidae). Fla. Entomol. 42:113-121.
- DODOO, Y. A. 1968. Comparisons of phytoseiid predator population in sprayed and unsprayed apple orchards in Cache Valley, Utah. Unpublished master's thesis, Utah State Univ., Logan. 46 pp.
- DOWNING, R. S., AND R. K. MOILLIET. 1967. Relative densities of predaceous and phytophagous mites on three varieties of apple trees. Can. Entomol. 99:738-741.
- DUKE, K. M., B. A. CROFT, AND C. D. JORGENSEN. 1970. Distribution and searching behavior of *Typhlodromus mcgregori*. J. Econ. Entomol. 63:221-227.
- EHARA, S. 1966. A tentative catalogue of predatory mites of Phytoseiidae known from Asia, with descriptions of five new species from Japan. Mushi 39:9-30.
- EL-BADRY, E. A., AND M. A. ZAHER. 1961. Life history of the predator mite, *Typhlodromus (Amblyseius) cucumeris* Oudemans (Acarina: Phytoseiidae). Bull. Soc. Entomol. Egypt 45:427-434.
- ENGLISH, L. L., AND R. SNETSINGER. 1957. The biology and control of *Eotetranychus multigigatus* (Ewing) a spider mite of honey locust. J. Econ. Entomol. 50:784-788.
- EVANS, G. O. 1952. On a new predatory mite of economic importance. Bull. Entomol. Res. 43:397-401.
- FLAHERTY, D. L., AND C. B. HUFFAKER. 1970. Biological control of Pacific mites and willamette mites in San Joaquin Valley vineyards. I. Role of *Metaseiulus occidentalis*. II. Influence of dispersion pattern of *Metaseiulus occidentalis*. Hilgardia 40:267-330.
- GARMAN, P. 1948. Mite species from apple trees in Connecticut. Bull. Conn. Agr. Exp. Sta. 396:372-377.
- . 1958. New species belonging to the genera *Amblyseius* and *Amblyseioopsis* with key to *Amblyseius*, *Amblyseioopsis* and *Phytoseiulus*. Ann. Entomol. Soc. Amer. 51:69-79.
- HERBERT, H. J. 1959. Note on feeding ranges of six species of predaceous mites. (Acarina: Phytoseiidae) in the laboratory. Can. Entomol. 91:812.
- HOVING, S. A., AND B. A. CROFT. 1977. Comparisons between *Typhlodromus longipilus* Nesbitt and *T. occidentalis* Nesbitt: taxonomy, distribution and hybridization. Ann. Entomol. Soc. Amer. 70:150-159.
- HOYT, S. C. 1969a. Population studies of five mite species on apple in Washington. Proc. 2d Intern. Congr. Acarology, Sutton-Bonnington, England (1967); 117-113.
- . 1969b. Integrated chemical control of insects and biological control of mites on apples in Washington. J. Econ. Entomol. 62:74-86.
- HUFFAKER, C. B., AND C. E. KENNETT. 1956. Experimental studies on predation: predation and cyclamen-mite populations on strawberries in California. Hilgardia 26:191-222.
- JORGENSEN, C. D. 1964. Ecology of mites on pomaceous fruit trees and related wild hosts in Hood River Valley. Unpublished Ph.D. dissertation, Oregon State Univ., Corvallis, Oregon. 147 p.
- . 1967. Ecology of Utah apple mites: a statement of the problem. Proc., Utah Acad. Sci., Arts, and Letters 44:265-274.
- KENNETT, C. E. 1958. Some predaceous mites of the subfamily *Phytoseiinae* and *Ascoseiinae* (Acarina: *Phytoseiidae*, *Ascoseiidae*) from central California with descriptions of new species. Ann. Entomol. Soc. Amer. 51:471-479.
- LAING, J. E. 1969. Life history and life table of *Metaseiulus occidentalis*. Ann. Entomol. Soc. Amer. 62:978-982.
- LEE, M. S., AND D. W. DAVIS. 1968. Life history and behavior of the predatory mite *Typhlodromus occidentalis* in Utah. Ann. Entomol. Soc. Amer. 61:251-255.
- LEETHAM, J. W., AND C. D. JORGENSEN. 1969. Overwintering phytoseiid mites in central Utah apple orchards. Great Basin Nat. 29:96-104.
- LEIGH, T. F. 1963. Considerations of distribution abundance and control of acarine pests of cotton. Advances in acarology, Vol. 1. Ithaca, N.Y.: Cornell Univ. Press, pp. 14-20.
- MACGILL, E. I. 1939. A gamasid mite (*Typhlodromus thrips* n. sp.), a predator of *Thrips tabaci* Lind. Ann. Appl. Biol. 26:309-317.
- MALCOLM, D. R. 1955. Biology and control of the timothy mite, *Paratetranychus pratensis* (Banks). Tech. Bull. Wash. Agric. Exp. Sta. No. 17:1-35.
- MCMURTRY, J. A., AND G. I. SCRIVEN. 1964. Studies on the feeding, reproduction, and development of *Amblyseius hibisci* (Acarina: Phytoseiidae) on various food substances. Ann. Entomol. Soc. Amer. 57:649-655.
- MONGKOLPRASITH, V. 1976. Phytoseiid predators of mite species in Utah apple orchards. Unpublished

- master's thesis, Brigham Young Univ., Provo, Utah. 60 p.
- MUMA, M. H. 1955. Phytoseiidae (Acarina) associated with citrus in Florida. *Ann. Entomol. Soc. Amer.* 48:262-272.
- . 1961. Subfamilies, genera and species of Phytoseiidae (Acarina: Mesostigmata). *Bull. Fla. St. Mus. Biol. Ser.* 5:267-302.
- . 1963. The genus *Calendromus* Muma, 1961 (Acarina: Phytoseiidae). *Fla. Entomol. Suppl.* 1:15-41.
- . 1964. Annotated list and key to Phytoseiidae (Acarina: Mesostigmata) associated with Florida citrus. *Fla. Agr. Exp. Sta. Tech. Bull.* 685-42 p.
- MUMA, M. H., AND H. A. DENMARK. 1970. Phytoseiidae of Florida. *Arthro. Fla. and Neighboring Land Areas.* 6:1-149.
- NELSON, E. E., AND C. D. JORGENSEN. 1969. Dispersal of *Bryobia* spp. and *Typhlodromus mcgregori* (Chant) within apple trees in central Utah. *Proc. Utah Acad. Sci. Arts and Letters* 45:168-181.
- NESBITT, H. H. J. 1951. A taxonomic study of the Phytoseiinae (Family Laelaptidae) predaceous upon Tetranychidae of economic importance. *Zool. Verh. Rijksmus. Natur. Hist. Leiden.* 12:1-64.
- OATMAN, E. R. 1965. Predaceous mite controls two-spotted spider mite on a strawberry. *Calif. Agri.* 19:6-7.
- . 1976. An ecological study of arthropod populations on apple in northeastern Wisconsin: Phytoseiid mite species on the foliage. *Environ. Entomol.* 5:63-64.
- OUDEMANS, A. C. 1930. *Acarologische CII. Ent. Ber.* 8:69-74.
- PARROTT, P. T., H. E. HODGKISS, AND W. J. SCHOENE. 1906. The Eriophyiidae Part I. The apple and pear mites. *New York Agr. Expt. Sta. Bull.* 283:302-303.
- PUTMAN, W. L. 1962. Life history and behavior of the predaceous mite *Typhlodromus* (T.) *caudiglaus* Schuster (Acarina: Phytoseiidae) in Ontario, with notes on the prey of related species. *Can. Entomol.* 94:163-177.
- PUTMAN, W. L., AND D. C. HERNE. 1964. Relations between *Typhlodromus caudiglaus* Schuster (Acarina: Phytoseiidae) and phytophagous mites in Ontario peach orchards. *Can. Entomol.* 96:925-943.
- RISTICH, S. S. 1956. Mass rearing and testing techniques for *Typhlodromus fallacis* Garman. *J. Econ. Entomol.* 49:476-479.
- SCHUSTER, R. O. 1957. A new species of *Typhlodromus* from California (Acarina: Phytoseiidae). *Pan-Pacific Entomol.* 33:203-205.
- . 1959. A new species of *Typhlodromus* near *T. bakeri* Garman and a consideration of the occurrence of *T. rhenanus* Oudemans in California. *Proc. Entomol. Soc. Wash.* 61:88-90.
- . 1966. Description of immature stages of three California species of phytoseiids, including notes on their biology. *Pan-Pacific Entomol.* 42:58-66.
- SCHUSTER, R. O., AND E. PRITCHARD. 1963. Phytoseiid mites of California. *Hilgardia* 34:191-285.
- SCHUSTER, R. O., AND R. GONZALEZ. 1963. Redescrptions and notes on *Amblyseius cucumeris* Oudemans (Acarina: Phytoseiidae). *Acarologia* 5:185-188.
- SCHUSTER, R. O., AND L. M. SMITH. 1960. The spermathecae as taxonomic features in phytoseiid mites of western North America. *Proc. Entomol. Soc. Wash.* 62:181-188.
- SMITH, J. C., AND L. D. NEWSOM. 1970. The biology of *Amblyseius fallacis* (Acarina: Phytoseiidae) at various temperatures and photoperiod regimes. *Ann. Entomol. Soc. Amer.* 63:460-462.
- SMITH, F. F., T. J. HENNEBERRY, AND A. L. BOSWELL. 1963. The pesticide tolerance of *Typhlodromus fallacis* Garman and *Phytoseiulus persimilis* A. & H. with some observations on efficiency of *P. persimilis*. *J. Econ. Entomol.* 53:274-278.
- TSUNG, D. L. 1972. Biological studies of *Amblyseius fallacis* and *Typhlodromus longipilus* (Acarina: Phytoseiidae) with particular emphasis on diapause. Unpublished Ph.D. dissertation. Rutgers Univ. State Univ. of New Jersey. 48 p.
- WOMERSLEY, H. 1954. Species of subfamily Phytoseiinae (Acarina: Laelaptidae) from Australia. *Austral. J. Zool.* 2:169-191.